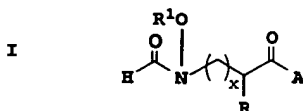


N-FORMYL HYDROXYLAMINE CONTAINING COMPOUNDS
USEFUL AS ACE INHIBITORS AND/OR NEP INHIBITORS

Summary of the Invention

- 5 This invention is directed to novel compounds possessing angiotensin converting enzyme (ACE) inhibitory activity and/or neutral endopeptidase (NEP) inhibitory activity and methods of preparing such compounds. This invention is also directed to
- 10 pharmaceutical compositions containing such ACE and/or NEP inhibiting compounds or pharmaceutically acceptable salts thereof and the method of using such compositions.

- 15 The compounds of this invention are those of the formula (I)

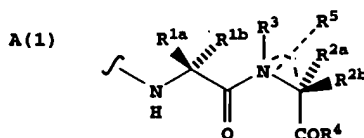


including a pharmaceutically acceptable salt thereof where:

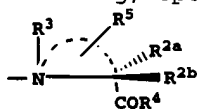
- 20 x is 0 or 1;
R is H, alkyl, alkenyl, aryl-(CH₂)_p-, heteroaryl-(CH₂)_p-, cycloheteroalkyl-(CH₂)_p-, or
- R can be joined together with the carbon to which it is attached to form a 3 to 7 membered ring
- 25 which may optionally be fused to a benzene ring;

p is 0 or an integer from 1 to 8; and

A is a dipeptide derivative of the structure

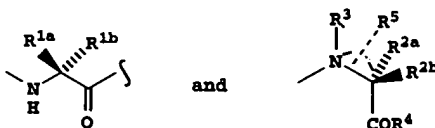


15 R^{1a} and R^{1b} or R^{2a} and R^{2b} may be joined together to the carbon to which they are attached to form a 3 to 7 membered ring, optionally fused to a



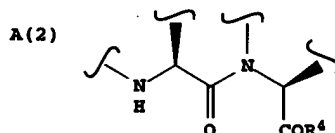
25 R^3 is H, alkyl or aryl $-(CH_2)_p-$;
 R^4 is OH, Oalkyl, O- $(CH_2)_p$ aryl- or $NR_1(R_2)$

with the proviso that in A(1) at least one of



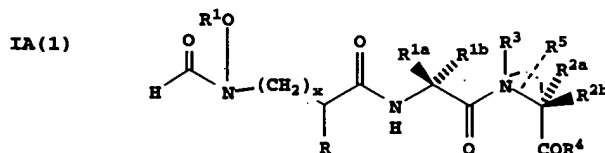
is other than a natural α -amino acid, and thus must be other than valine, leucine, phenylalanine, tyrosine, serine, cysteine, threonine, methionine, aspartic acid, glutamic acid, arginine, lysine or proline.

In addition, A can be a conformationally restricted dipeptide mimic which has the structure

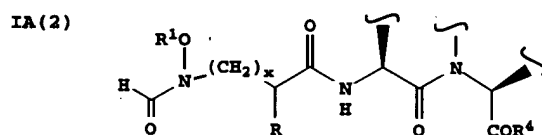


and is a non-proteinogenic dipeptide.

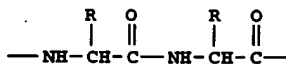
Thus, the compound of formula I include



and

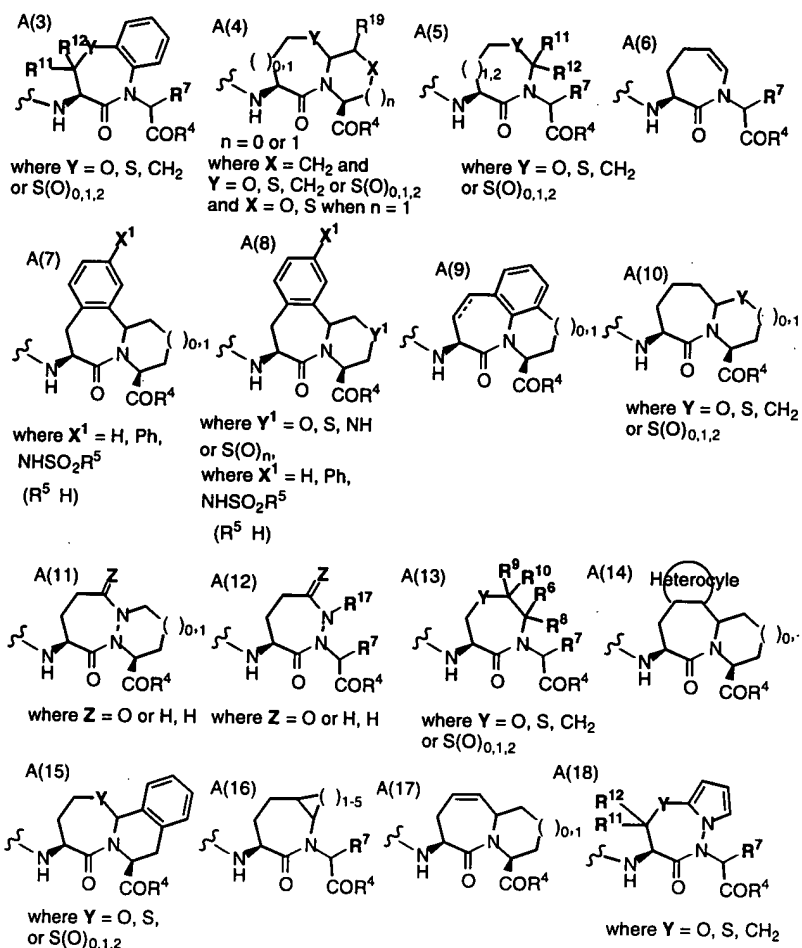


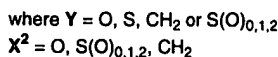
The term "conformationally restricted dipeptide mimic" refers to a structural skeleton which has the attributes of a conventional dipeptide



but having enhanced biological properties due to additional bonds which limit the rotational freedom.

Examples of the A(2) dipeptide mimics include any of the conformationally restricted dipeptide mimics set out below.

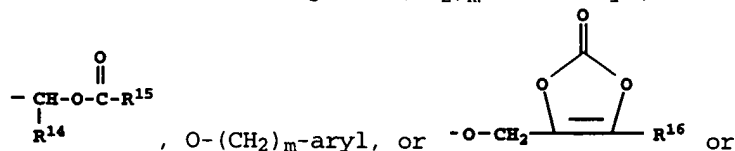



$$\text{C}=\text{O} \quad ;$$

R¹⁰ and R⁶ are independently selected from hydrogen, alkyl, substituted alkyl, alkenyl, substituted alkenyl, cycloalkyl -(CH₂)_m-, aryl-(CH₂)_m, substituted aryl -(CH₂)_m-, and heteroaryl-(CH₂)_m-, or R⁶ and R¹⁰ taken together with the carbon to which they are attached complete a saturated cycloalkyl ring of 3 to 7 carbons, R⁶ and R⁸ taken together with the carbon to which they are attached

complete a saturated cycloalkyl ring of 3 to 7 carbons, or R⁹ and R¹⁰ taken together with the carbon to which they are attached complete a saturated cycloalkyl ring of 3 to 7 carbons;

- 5 m is zero or an integer from 1 to 6;
 R⁴ is OH, Oalkyl, O-(CH₂)_m-heteroaryl,



NR₁(R₂);

- where R₁ and R₂ are independently H, alkyl,
 10 aryl(CH₂)_p, aryl or heteroaryl;
 R¹⁴ is hydrogen, lower alkyl, cycloalkyl, or
 phenyl;
 R¹⁵ is hydrogen, lower alkyl, lower alkoxy or
 phenyl;
 15 R¹⁶ is alkyl or aryl-(CH₂)_m-; and
 R¹⁷ is hydrogen, alkyl, substituted alkyl,
 alkenyl, substituted alkenyl, cycloalkyl-(CH₂)_m-,
 aryl-(CH₂)_m-, substituted aryl-(CH₂)_m-, or
 heteroaryl-(CH₂)_m-.

- 20 R¹⁸ is H, alkyl or alkenyl, and R¹⁸ and R¹⁷ may
 be taken together with the carbon and nitrogen to
 which they are attached to complete a saturated N-
 containing ring of 5 or 6 ring members.

- R¹⁹ is H or an alkyl, and in A(4), R¹⁹ and X
 25 (which is CH₂) together with the carbons to which
 they are attached may form an aromatic ring of
 carbons (as in A(15)).

- The starting compounds H-A(1) and H-A(2) are
 described in the literature or are obtained by
 30 modifications of known procedures. For example, the

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starting compounds of formula H-A(1) or H-A(2)
wherein A(1) or A(2) is as defined in formulas A(5),
A(13), A(16), A(21), where Y (where present) is CH₂
are disclosed by Thorsett et al., J. Med. Chem., 29,
5 p. 251 - 260 (1988), Harris et al. in U.S. Patents
4,587,050, 4,587,238, 4,629,787 and Yanagisawa et al.
in U.S. Patent 4,734,410.

The starting compounds of formula H-A(1) or H-
A(2) wherein A(1) or A(2) is as defined in formulas
10 A(3) and A(13) where Y is S(O)_n are disclosed by
Yanagisawa et al., J., Med. Chem., 30, p. 1984 - 1991
(1987) and 31, p. 422 - 428 (1988), Karanewsky in
U.S. Patent 4,460,579, Cheung et al. in U.S. Patent
4,594,341, and Yanagisawa et al. in U.S. Patent
15 4,699,905.

The starting compounds of formula H-A(1) or H-
A(2) wherein A(1) or A(2) is as defined in formula
A(5) are disclosed by Karanewsky in U.S. Patents
4,460,579 and 4,711,884.

The starting compounds of formula H-A(1) or H-
A(2) wherein A(1) or A(2) is as defined in formulas
A(3) (Y is -CH₂-, and A(21) are disclosed by Watthey
et al., J. Med. Chem., 28, p. 1511 - 1516 (1985) and
Watthey in U.S. Patents 4,410,520, 4,470,988,
25 4,473,575, 4,537,885 and 4,575,503 and also by
Parsons et al., Biochemical & Biophysical Research
Comm., 117, p. 108 - 113 (1983) and in U.S. Patent
4,873,235.

The starting compounds of formula H-A(1) or H-
30 A(2) wherein A(1) or A(2) is as defined in formula
A(3) and Y is S or O are disclosed by Slade et al.,
J. Med. Chem., 28, p. 1517 - 1521 (1985) and in U.S.
Patent 4,477,464 and Itoh et al., Chem. Pharm. Bull.,
34, p. 1128 - 1147 (1986) and 34, p. 2078 - 2089

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The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formula A(22) are disclosed by Flynn et al in U.S. Patent 4,973,585.

The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formula A(10) and Y is CH₂, and is as defined in formula A(23) where X² is CH₂ is disclosed by Thorsett, Actual. Chim. Ther., 13, p. 257-268 (1986).

30 The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formula A(12) are disclosed by Huang et al. in U.S. Patent 4,465,679.

The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formula A(18) are disclosed by Bolos et al. in Tetrahedron, 48, p. 9567-9576 (1992).

- 5 The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formulas A(4) and A(15) are disclosed in European Patent Application 0629627A2.

- 10 The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formula A(9) are disclosed in U.S. application Serial No. 100,408 (file HA611a).

- 15 The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formulas A(7) and A(8) are disclosed in European Patent Application 481,522 (Flynn et al) and European Patent Application 0534363A2 (Warshawsky et al).

- 20 The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formula A(14) are disclosed in U.S. application Serial No. 153,854 (file HA615).

- 25 The starting compounds of formula H-A(1) or H-A(2) wherein A(1) or A(2) is as defined in formula A(17) are disclosed in European Patent Application 0599444A1 (Barrish et al).

- 30 In addition, in accordance with the present invention, a pharmaceutical composition is provided which includes a therapeutically effective amount of compound I and a pharmaceutically acceptable carrier therefor.

The pharmaceutical composition as defined above will be useful in the treatment of cardiovascular diseases such as hypertension and/or congestive heart failure.

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SECRET

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The term "cycloalkyl" refers to saturated rings of 3 to 7 carbon atoms.

The term "heteroaryl" refers to unsaturated rings of 5 or 6 atoms containing one or two O and S atoms and/or one to four N atoms provided that the total number of hetero atoms in the ring is 4 or less, which may optionally be substituted with one, two or three substituents which include alkyl, aryl, cycloalkyl, alkoxy or halo. The heteroaryl ring is attached by way of an available carbon or nitrogen atom. Preferred heteroaryl groups include 2-, 3-, or 4-pyridyl, 4-imidazolyl, 4-thiazolyl, 2- and 3-thienyl, and 2- and 3-furyl. The term heteroaryl also includes bicyclic rings wherein the five or six membered ring containing O, S, and N atoms as defined above is fused to a benzene or pyridyl ring. Preferred bicyclic rings are 2- and 3-indolyl and 4- and 5-quinolinyl. The mono or bicyclic heteroaryl ring can also be additionally substituted at an available carbon atom by a lower alkyl, halo, hydroxy, benzyl, or cyclohexylmethyl. Also, if the mono or bicyclic ring has an available N-atom such N atom can also be substituted by an N-protecting group such as

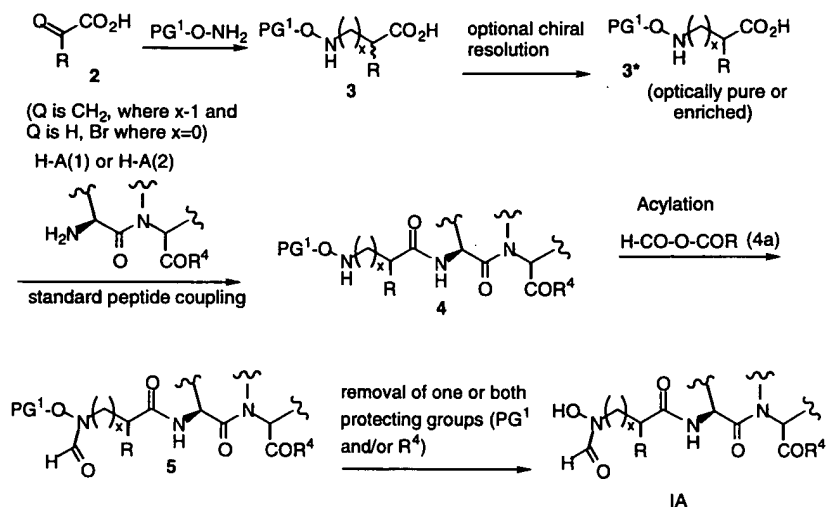


2,4-dinitrophenyl, lower alkyl, benzyl, or

5 benzhydryl.

The compounds of formula I of the invention may be prepared as outlined in Reaction Scheme I set out below (where x is 0 or 1).

10 Reaction Scheme I



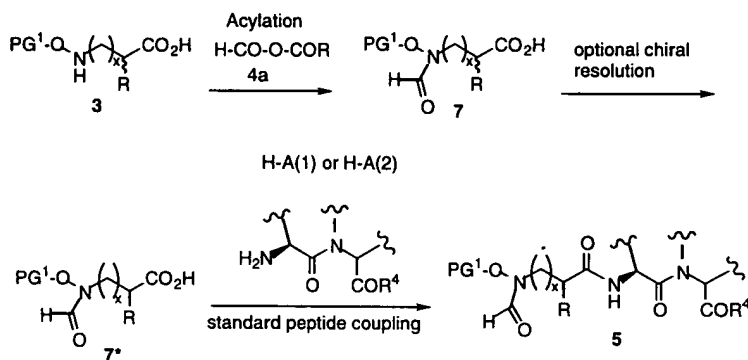
As shown in Scheme I, acid 2 may be reacted
 15 with a suitably O-protected (e.g. PG¹ is benzyl, p-methoxybenzyl, tetrahydropyranyl, trityl, benzhydryl, etc.) hydroxylamine to give the adduct 3. Compound 3 may be coupled directly with amine H-A(1) or H-A(2) to give a mixture of diastereomers which may be
 20 separated or preferably compound 3 may be optically enriched or purified, employing conventional

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techniques, to give **3***. Subsequent coupling with **H-A(1)** or **H-A(2)** gives **4** in diastereomerically enriched or pure form. Reaction of the hydroxylamine nitrogen of **4** with a formylating agent affords **5**. At this point one or both protecting groups may be removed, either sequentially or simultaneously, to produce compound of the invention **IA**. For example, when PG^1 is benzyl and R^4 is Obenzyl, both may be removed by hydrogenolysis. When PG^1 is benzyl and R^4 is -Oethyl or -Oethyl , the PG^1 group may be removed by hydrogenolysis and the ester group may be converted to the acid by base hydrolysis. PG^1 groups such as THP or trityl may be removed by treatment with strong acid such as hydrogen chloride or trifluoro acetic acid in a protic solvent.

Alternately, compounds of the invention **IA** may be obtained by the route depicted in Scheme II (where x is 0 or 1).

Reaction Scheme II



As seen in Reaction Scheme II, compound **3** may be formylated with an formylating agent **4a** to give acid compound **7**. This acid may be coupled with **A(1)**

or A(2) directly or optically resolved to give 7* and then coupled to give compound 5. Compound 5 is then converted to compound of the invention IA as described above.

5 The compounds of formula I of the invention contain one or more asymmetric centers. Thus, these compounds can exist in diastereoisomeric forms or in mixtures thereof and all of such forms are within the scope of this invention. The above described
10 processes can utilize racemates, enantiomers, or diastereomers as starting materials. When diastereomeric compounds are prepared, they can be separated by conventional chromatographic or fractional crystallization methods.

15 The compounds of formula I of the invention can be isolated in the form of a pharmaceutically acceptable salt. Suitable salts for this purpose are alkali metal salts such as sodium and potassium, alkaline earth metal salts such as calcium and
20 magnesium, and salts derived from amino acids such as arginine, lysine, etc. These salts are obtained by reacting the acid form of the compound with an equivalent of base supplying the desired ion in a medium in which the salt precipitates or in aqueous
25 medium and then lyophilizing.

 The compounds of formula I of the invention are inhibitors of angiotensin converting enzyme and/or neutral endopeptidase. Thus, the compounds of formula I including their pharmaceutically acceptable
30 salts are useful in the treatment of physiological conditions in which either angiotensin converting enzyme inhibitors or neutral endopeptidase inhibitors have been shown to be useful. Such conditions include cardiovascular diseases, particularly,

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hypertension, congestive heart failure, renal failure, and hepatic cirrhosis, as well as analgesic activity. The compounds of formula I are also inhibitors of other metalloproteases such as the matrix metalloproteases, for example, gelatinase, collagenase and stromelysin and thus are useful in the treatment of osteoarthritis, rheumatoid arthritis, metastatic tumors, and angiogenesis.

Diuresis, natriuresis, and blood pressure reduction are produced in a mammalian host such as man by the administration of from about 1 mg. to about 100 mg. per kg. of body weight per day, preferably from about 1 mg. to about 50 mg. per kg. of body weight per day, of one or more of the compounds of formula I or a pharmaceutically acceptable salt thereof. The compounds of formula I are preferably administered orally, but parenteral routes such as subcutaneous, intramuscular, and intravenous can also be employed. The daily dose can be administered singly or can be divided into two to four doses administered throughout the day.

The ACE and/or NEP inhibitors of formula I can be administered in combination with human ANF 99 - 126. Such combination would contain the inhibitor of formula I at from about 1 to about 100 mg. per kg. of body weight and the human ANF 99 - 126 at from about 0.001 to about 0.1 mg. per kg. of body weight.

The ACE and/or NEP inhibitors of formula I can be administered in combination with other classes of pharmaceutically active compounds. For example, a calcium channel blocker, a potassium channel activator, a cholesterol reducing agent, etc.

The ACE and/or NEP inhibitors of formula I or a pharmaceutically acceptable salt thereof and other

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of formula I wherein

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R is alkyl or arylalkyl, and

R1a R1b



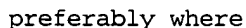
is preferably a non-proteinogenic

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R1a and R1b together with the carbon to which

25

Also preferred are compounds where A is A(1).



COR⁴ and is a non-proteino-

genic amino acid where R^3 is H, alkyl, such as methyl

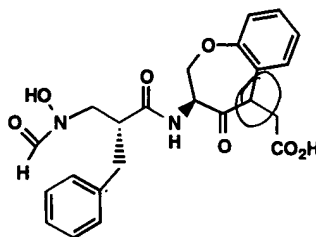
or ethyl, aryl such as phenyl, or arylalkyl, such as benzyl,

- R^{2a} and R^{2b} are independently selected from H, alkyl, aryl, arylalkyl (with at least one of R^{2a} and R^{2b} being other than H) or R^{2a} and R^{2b} together with the carbon to which they are attached form a 3-7 membered ring, preferably 5- or 6-membered ring.

Also preferred are compounds where A is A(2) wherein R^4 is OH.

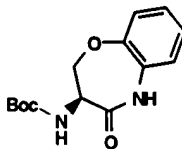
- The following Examples represent preferred embodiments of the present invention.

Example 1

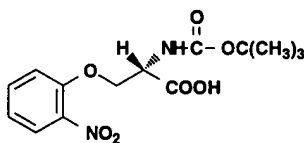


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A.



A(1).

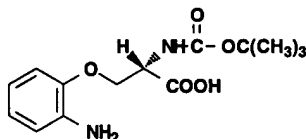


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A solution of BOC-L-serine (24.3 g, 0.118 mole) in dry dimethylformamide (25 ml) was added dropwise over a period of 1.0 hour to a cooled (0°,

ice-salt bath) suspension of 60% NaH (10.1 g, 0.25 mole) in dry dimethylformamide (200 ml) and stirring was continued at 0° until the frothing subsided (ca. 2.0 hours). The reaction mixture was treated dropwise with 1-fluoro-2-nitrobenzene (14.3 ml, 0.13 mole) over a period of 20 minutes, stirred at 0° under argon for 4.0 hours then poured into ice-water (750 ml) and extracted with Et₂O (2 x 100 ml). The aqueous phase was brought to pH 1.0 with 6 N HCl (70 ml), extracted with EtOAc (3 x 500 ml) and the combined organic extracts were washed with brine (100 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness and dried *in vacuo*. The crude product mixture was chromatographed on a silica gel column (Merck), eluting the column with CH₂Cl₂:CH₃OH:HOAc (100:5:0.2) to give title compound as a thick yellow syrup (27.222 g, 70.7%) with consistent ¹H-NMR and ¹³C-NMR spectral data. TLC: R_f 0.27 (Silica gel; CH₂Cl₂:CH₃OH:HOAc- 100:5:0.5; UV, PMA).

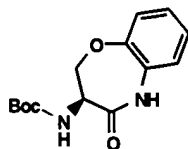
A(2).



A solution of Part A(1) compound (27.1 g, 83 mmoles) in dry methanol (500 ml) was treated with 10% Pd/C (900 mg) and hydrogenated at 40 psi for 2.0 hours. The reaction mixture was filtered through a Celite® pad in a millipore unit, washing the pad well with CH₃OH (5 x 100 ml). The dark filtrate was evaporated to dryness and dried *in vacuo* to give a dark solid. The crude product was triturated with CH₂Cl₂:Hexane (1:4) to give title compound as a light

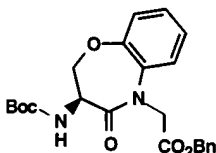
tan solid (17.69 g, 71. %) with consistent $^1\text{H-NMR}$ and $^{13}\text{C-NMR}$ spectral data. TLC: R_f 0.15 (Silica gel; $\text{CH}_2\text{Cl}_2:\text{CH}_3\text{OH}:\text{HOAc}$ - 20:1:1; UV).

5 A(3).



A solution of Part A(2) compound (16.69 g, 56.3 mmol) in dry dimethylformamide (121 ml) was
 10 treated with 1-ethyl-3-(3-dimethylaminopropyl)-carbodiimide (10.64 g, 55.5 mmol) and stirred at room temperature for 3.0 hours. The reaction mixture was partitioned between EtOAc (2 x 492 ml) and 1.0 N NaHCO_3 (492 ml), and the combined organic extracts
 15 were washed with H_2O (3 x 492 ml), brine (492 ml), dried (anhydrous MgSO_4), filtered, evaporated to dryness and dried in vacuo. The crude product was chromatographed on a silica gel column (Merck), eluting the column with EtOAc:Hexane mixtures (1:4;
 20 1:2; 1:1) to give title compound as off-white crystals (10.5 g, 72.4%) with consistent $^1\text{H-NMR}$ and $^{13}\text{C-NMR}$ spectral data. TLC: R_f 0.40 (Silica gel; EtOAc:Hexane- 1:4; UV).

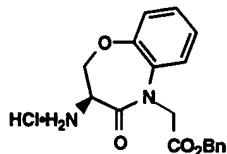
25 B.



A solution of Part A compound (640 mg, 2.30 mmol) in dry THF (12 mL) at 0°C was treated with

LiN(TMS)₂ (1.0 M in THF, 2.60 mL, 2.60 mmol) followed approximately 30 seconds later with benzyl bromoacetate (475 μ L, 687 mg, 3.0 mmol). After 25 minutes, the mixture was quenched with saturated NH₄Cl, diluted with H₂O, and extracted with EtOAc. The EtOAc extract was washed with H₂O and brine, then dried (Na₂SO₄), filtered and stripped to give a yellow oil. Flash chromatography (Merck SiO₂, 3/7-EtOAc/hexanes as eluant) provided title compound (967 mg, 98%) as a colorless oil/foam.

C.



A solution of Part B compound (960 mg, 2.25 mmol) in 1,4-dioxane (4 mL) was treated with a solution of 4.0 M HCl in 1,4-dioxane (6 mL) at room temperature. After 3 hours, the mixture was concentrated in vacuo, triturated with Et₂O to give a solid and stripped to afford title compound (858 mg, 105% of theory). m.p. 152-155°C.

Chemical structure of compound 10: BrCC(=O)N(Cc1ccccc1)CC(=O)N[C@H]2C(=O)N(Cc3ccccc3)C(=O)O2

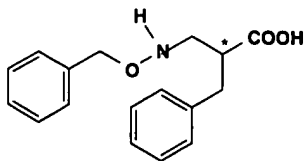
CC(=C)Cc1ccccc1C(=O)O

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D(2).

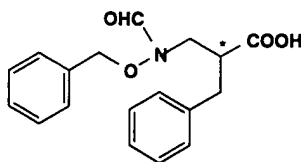


(J. Med. Chem. 28, 1985, 1167)

- 5 A solution of Part D(1) compound (8.9 g, 54.9
mmoles) and O-benzylhydroxylamine (26.7 g, 0.23 mole)
in absolute EtOH (9.0 ml) was refluxed for 7 days,
cooled to room temperature and evaporated to dryness.
The residual syrup was dissolved in 1.0 N NaOH (55
10 ml), stirred for 15 minutes then extracted with EtOAc
(4x 18 ml). The organic phase was washed with H₂O (3
x 10 ml) and the aqueous extracts were combined and
acidified to pH 2.0 with 1.0 N HCl (62 ml). The
acidic aqueous phase was then extracted with EtOAc (5
15 x 75 ml) and the combined organic extracts washed
with H₂O (2 x 30 ml), dried (anhydrous Na₂SO₄),
filtered, evaporated to dryness and dried in vacuo.
The crude product (3.93 g, 25.1%) was triturated with
Et₂O:Hexane (1:4; 2 x 25 ml) and all solids obtained
20 were dissolved in CH₂Cl₂ and filtered, washing the
insoluble precipitates with CH₂Cl₂. The clear
filtrate was evaporated and dried in vacuo to give
title compound as an opaque colorless solid with
consistent ¹H-NMR and ¹³C-NMR spectral data.
25 TLC: R_f 0.33 (Silica gel; CH₂Cl₂:MeOH- 9:1; UV, PMA).
M.p. 69-71°C.

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D(3).

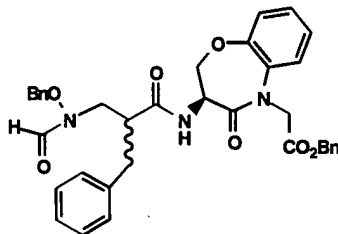


5 A cooled (0°C, ice-salt bath) mixture of HCOOH (17.5ml) and acetic anhydride (Ac₂O) (1.75 ml) was stirred for 20 minutes, treated with Part D(2) compound (1.0 g, 3.5 mmoles) and stirring was continued at 0°C for another 3.0 hours. The reaction mixture was stripped to dryness, evaporated from Et₂O

10 (2 x 25 ml), toluene (20 ml) and hexane (2 x 50 ml) then dried *in vacuo* to give title compound as a thick syrup (1.096 g, 100% crude yield) with consistent ¹H-NMR and ¹³C-NMR spectral data. TLC: R_f 0.23 (Silica gel; CH₂Cl₂:MeOH- 9:1; UV, PMA).

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D(4).

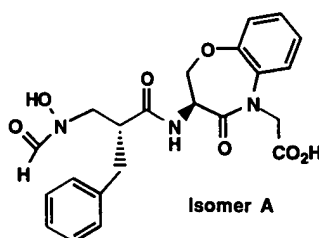


20 A solution of Part D(3) compound (366 mg, 1.19 mmol) in CH₂Cl₂ (9 mL) at 0°C was treated with HOBT hydrate (210 mg) followed by EDAC (230 mg, 1.20 mmol). After 20 minutes, the mixture was treated with Part C amine hydrochloride 3 (390 mg, 1.07 mmol) followed by 4-methylmorpholine (200 μL, 184 mg, 1.8

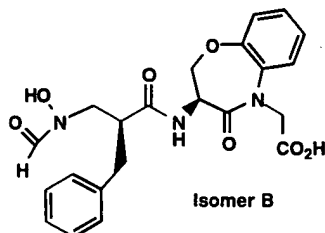
25 mmol). The mixture was stirred at 0°C for 1 hour and at room temperature for 2 hours. The reaction was

partitioned between EtOAc and 5% KHSO₄. The EtOAc extract was washed successively with H₂O, 50% saturated NaHCO₃ and brine, then dried (Na₂SO₄), filtered and stripped. Flash chromatography (Merck SiO₂, 50% to 60% EtOAc in hexanes as eluant) provided title compound (550 mg, 84%) as a white foam which was shown by NMR and HPLC to be a 1:1 mixture of diastereomers.

10 E.



A solution of Part D compound (535 mg, 0.87 mmol) in MeOH (10 mL) was hydrogenated (balloon) over 10% Pd/C (123 mg) at room temperature for 2.75 hours. The solvent was filtered through Celite and the filtrate was stripped to give a diastereomeric mixture of title Isomer A and Isomer B



20 Trituration of a solution of the residue in MeOH with Et₂O provided 350 mg of the diastereomeric mixture. Approximately 255 mg of this mixture was separated by preparative HPLC (YMC S5 ODS 30 x 250 mm column; flow rate 25 mL/min detecting at 220 nm; 40 to 100% B over a 30 minute

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linear gradient (solvent A: 90% H₂O-10% MeOH-0.1% TFA; solvent B: 10% H₂O-90% MeOH-0.1% TFA); title Isomer A t_R = 14.4 min; separation performed in three runs).

The desired fractions were stripped, azetroped with
 5 EtOAc, re-dissolved in EtOAc and triturated with Et₂O to give title Isomer A (105.5 mg) as an off-white solid.

MS: (M+NH₄)⁺ 459; (M-H)⁻ 440

10

HPLC YMC S3 ODS column (6.0 x 150 mm); eluted with B:A solvent mixture, 40 to 100% B over a 20 minute linear gradient (solvent A: 90% H₂O-10% MeOH-0.2% H₃PO₄; solvent B: 0% H₂O-90% MeOH-0.2% H₃PO₄); flow
 15 rate 1.5 mL/min detecting at 220 nm; t_R = 9.67 min (96.0%).

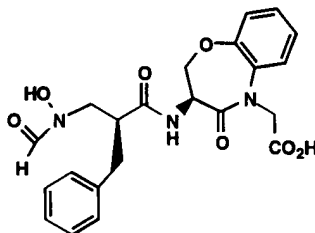
Anal. Calc'd for C₂₂H₂₃N₃O₇•1.6H₂O•0.1EtOAc•0.1Et₂O

C, 56.29; H, 5.80; N, 8.64

Found: C, 56.21; H, 5.15; N, 8.29.

20

Example 2



25

A solution of Example 1 Part E Isomers A and B (1:1 mixture of diastereomers, 535 mg, 0.87 mmol) in MeOH (10 mL) was hydrogenated (balloon) over 10% Pd/C (123 mg) at room temperature for 2.75 hours. The solvent was filtered through Celite and the filtrate

was stripped to give a diastereomeric mixture of Isomers A and B. Trituration of a solution of the residue in MeOH with Et₂O provided 350 mg of the diastereomeric mixture. Approximately 255 mg of this mixture was separated by preparative HPLC (YMC S5 ODS 30 x 250 mm column; flow rate 25 mL/min detecting at 220 nm; 40 to 100% B over a 30 minute linear gradient (solvent A: 90% H₂O-10% MeOH-0.1% TFA ; solvent B: 10% H₂O-90% MeOH-0.1% TFA); Isomer B t_R = 18.6 min; separation performed in three runs). The desired fractions were stripped, azetroped with EtOAc, re-dissolved in EtOAc and triturated with Et₂O to give Isomer B (88.0 mg) as an off-white solid.

15 MS: (M+NH₄)⁺ 459; (M-H)⁻ 440

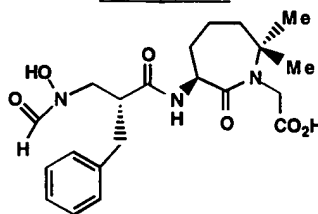
HPLC YMC S3 ODS column (6.0 x 150 mm); eluted with B:A solvent mixture, 40 to 100% B over a 20 minute linear gradient (solvent A: 90% H₂O-10% MeOH-0.2% H₃PO₄; solvent B: 0% H₂O-90% MeOH-0.2% H₃PO₄); flow rate 1.5 mL/min detecting at 220 nm; t_R = 13.8 min (94.0%).

Anal. Calc'd for C₂₂H₂₃N₃O₇·1.5H₂O·0.2Et₂O

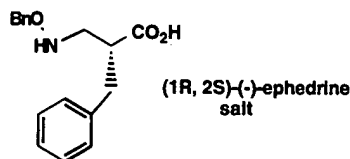
C, 56.66; H, 5.84; N, 8.69

25 Found: C, 56.84; H, 5.22; N, 8.42.

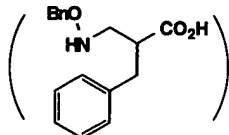
Example 3



A.



A solution of Example 1 Part D(1) compound



5 (2.563 gm, 8.98 mmol) in CH_3CN (20 mL) was treated with (1R,2S)-(-)-ephedrine (1.522 gm, 9.2 mmol) and stirred until homogeneous. Most of the solvent was removed by rotary evaporation and the residue was dissolved in Et_2O (25 mL) and treated

10 with hexane (16 mL) in portions until the mixture was slightly turbid. The solution was seeded and let stand overnight at room temperature. The precipitate was collected by filtration and rinsed with 1:1 Et_2O :hexanes and dried to afford 2.101 gm of white

15 crystals ($[\alpha]_D = -16.4^\circ$ (c 0.6, CH_2Cl_2)). The solid (2.087 gm) was dissolved in CH_2Cl_2 , concentrated and diluted with Et_2O (18 mL) and hexane (8 mL) and seeded. The precipitate was collected by filtration and washed with 1:1- Et_2O :hexanes followed by hexanes

20 to give title compound (1.995 gm) which was diastereomerically enriched in one isomer but not diastereomerically pure ($[\alpha]_D = -17.0^\circ$ (c 0.6, CH_2Cl_2)).

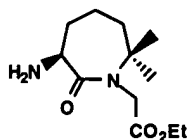
mp 110-114°C

25

Material suitable for x-ray crystallographic analysis was obtained by repeated recrystallization of the solid from CH_3CN . mp 117-119°C;

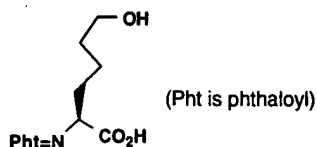
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B.



5

B(1).



To a stirred solution of L-(+)-hydroxynor-leucine (75 g, 509.6 mmole) and sodium carbonate (54 g, 509.6 mmole) in water (900 ml) at room temperature under argon was treated with N-ethoxy-carbonyl-phthalimide (111.7 g, 509.6 mmole). After being stirred for 2.0 hours, the resulting solution was filtered through a pad of celite. The filtrate was cooled in an ice bath and carefully acidified to pH=3 with 6N HCl solution. The white solid which had precipitated was filtered and dried over P₂O₅ in vacuo to afford Compound 1 (124.5 g) in 88.1% yield.

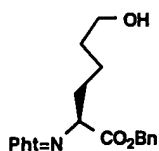
20

M.P. 162°C

$^1\text{H-NMR}$ (DMSO): δ = 1.32 (m, 6H), 2.13 (m, 2H), 4.38 (s, OH), 5.75 (m, 1H), 7.92 (m, 4H) ppm

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B(2) .

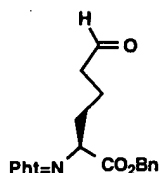


To a stirred slurry of Part B(1) compound
5 (124.5 g, 0.449 mole) and cesium carbonate (73.2 g,
0.225 mole) in DMF (1.25 L) at room temperature under
argon was added benzyl bromide (98.4 g, 0.575 mole).
After 2.5 hours, the resulting solution was poured
into EtOAc (3.0 L), washed with water (3X), 5% LiCl
10 solution and brine, dried over anhydrous Mg_2SO_4 and
evaporated in vacuo to afford title compound (142 g)
as an oil in 86.1% yield.

¹H-NMR (CDCl₃): δ = 1.50 (m, 4H), 2.32 (m, 2H), 3.62 (m, 2H), 4.91 (dd, 1H), 5.22 (d, 2H), 7.31 (m, 5H), 7.77 (m, 2H), 7.86 (m, 2H) ppm

C¹³-NMR (CDCl₃): 22.62, 28.46, 31.91, 52.32, 62.32, 67.46, 123.55, 128.06, 128.31, 128.53, 131.77, 134.23, 135.28, 167.76, 169.25 ppm

B(3).



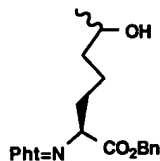
25 To a stirred and chilled (-78°C , Dry ice-IPA bath) oxalyl chloride solution (2.0 M solution in CH_2Cl_2 , 16.3 ml, 32.6 mmole) under argon was added dropwise a solution of dimethyl sulfoxide (4.64 ml, 65.32 mmole) in dry CH_2Cl_2 (10 ml). After the

addition was complete, the solution was stirred at -78° for 15 minutes, then treated with a solution of Part B(2) compound (10g, 27.22 mmole) in dry CH₂Cl₂ (70 ml), stirred at -78° for another 15 minutes and slowly treated with triethylamine (16 ml). The resulting solution was stirred at -78° for 15 minutes, gradually warmed up to 0°, poured into 1:1 EtOAc-Et₂O (500 ml), washed with 1.0 N HCl solution, water and brine, dried over anhydrous Mg₂SO₄ and evaporated in vacuo to afford title compound (10 g) as a light yellow oil in 100% yield.

¹H-NMR (CDCl₃): δ = 1.66 (m, 2H), 2.40 (m, 4H), 4.90 (dd, 1H), 5.18 (d, 2H), 7.35 (m, 5H), 7.74 (m, 2H), 7.86 (m, 2H), 9.72 (s, 1H) ppm

¹³C-NMR (CDCl₃): 18.66, 27.99, 42.87, 51.83, 67.47, 123.50, 128.00, 128.26, 128.44, 131.58, 134.21, 135.04, 167.55, 168.80, 201.31 ppm

B(4).



A stirred and chilled (0°C, ice bath) solution of Part B(3) compound (10.1 g, 27.64 mmole) in dry CH₂Cl₂ (100 ml) under argon was treated with a solution of trimethylaluminum (2.0 M solution in hexane, 23.4 ml, 46.8 mmole). The resulting solution was stirred for 45 minutes, quenched with 100 ml of a saturated NH₄Cl solution (foaming) and partitioned between 1:1 Et₂O-water (400 ml). The organic layer

5

TLC: Silica gel, 6:4 EtOAc-hexane, R_f = 0.42, UV and PMA.

10

15

B (5) .



29

30

To a stirred and chilled (-78°C , Dry ice-IPA bath) oxalyl chloride solution (2.0 M solution in CH_2Cl_2 , 257.3 ml, 514.6 mmole) under argon was added CH_2Cl_2 (300ml). To this solution, a solution of dimethyl sulfoxide (80.4 g, 1.03 mole) in dry CH_2Cl_2 (30 ml) was added dropwise. After the addition was complete, the reaction mixture was stirred at -78° for 20 minutes, treated with a solution of Part B(4) compound (151 g, 395.88 mmole) in dry CH_2Cl_2 (700 ml), stirred at -78°C for another 20 minutes and slowly treated with triethylamine (300 ml). The

resulting solution was stirred at -78° for 15 minutes, gradually warmed up to 0° , poured into 1:1 EtOAc-Et₂O (3 L), washed with 1.0 N HCl solution, water and brine, dried over anhydrous MgSO₄ and
 5 evaporated in vacuo to afford title compound (149.4 g) as a yellow oil in 99.5% yield.

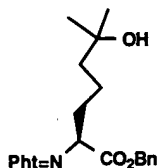
TLC: Silica gel, 6:4 EtOAc-hexane, R_f=0.5, UV and PMA.

10

¹H-NMR (CDCl₃): δ = 1.60 (m, 2H), 2.10 (s, 3H), 2.26 (m, 2H), 2.47 (m, 2H),, 4.90 (dd, 1H), 5.19 (d, 2H), 7.30 (m, 5H), 7.74 (m, 2H), 7.84 (m, 2H) ppm

15 ¹³C-NMR (CDCl₃): 20.15, 27.93, 29.84, 42.47, 51.89, 67.40, 123.46, 127.97, 128.23, 128.43, 131.61, 134.17, 135.10, 167.57, 168.93, 207.80 ppm

B(6).



20

A chilled (-78°C , Dry ice-IPA Bath) and stirred solution of titanium(IV) chloride (112.05 g, 590.65 mmole) in CH₂Cl₂ (1.5 L) under argon was
 25 treated with methylmagnesium chloride (3 M solution in THF, 196.9 ml, 590.65 mmole). The black solution was allowed to warm up to -35°C and a solution of Part B(5) compound (149.4g, 393.77 mmole) was added dropwise. After the addition was complete, the
 30 resulting solution was allowed to warm up to 0°C , stirred at 0°C for 2 hours and quenched with

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saturated NH_4Cl solution. The CH_2Cl_2 layer was separated. The aqueous layer was extracted with CH_2Cl_2 (2x700 ml). The CH_2Cl_2 extracts were combined, washed with brine, dried over anhydrous Mg_2SO_4 and
 5 evaporated in vacuo. The black residue was passed through a pad of silica gel (E. Merck, 230-400 mesh, 900 g) eluting with EtOAc-hexane (1:1) to afford a tlc-homogeneous title compound (144.8 g) as a yellow oil in 93% in yield.

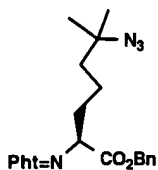
10

TLC: Silica gel, 1:1 EtOAc-hexane, $R_f=0.4$, UV and PMA.

$^1\text{H-NMR}$ (CDCl_3): $\delta=1.14$ (s, 6H), 1.45 (m, 4H), 2.30
 15 (m, 2H), 4.90 (dd, 1H), 5.19 (d, 2H), 7.30 (m, 5H), 7.74 (m, 2H), 7.86 (m, 2H) ppm

$^{13}\text{C-NMR}$ (CDCl_3): 20.88, 29.00, 29.17, 42.78, 52.13, 67.35, 70.47, 123.44, 127.95, 128.19, 128.41, 131.66,
 20 134.11, 167.66, 169.14 ppm

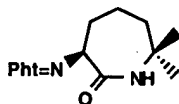
B(7).



25 A stirred solution of Part B(6) compound (44.3 g, 364.89 mmole) and azidotrimethylsilane (63.06 g, 547.34 mmole) in dry CH_2Cl_2 (2.2 L) at room temperature under argon was treated with boron trifluoride diethyl etherate (67.32 g, 474.36 mmole).
 30 After being stirred for 5 days, the resulting solution was quenched with water (1.5 L). The

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B(8).



A solution of Part B(7) compound (124.8 g, 296.81 mmole) and 10% Pd/C (32g) in dry DMF (2.0 L) was hydrogenated for 24 hours. After completion, argon was bubbled through the reaction mixture to remove excess hydrogen and methyl sulfide (2.6 ml) was added to poison the palladium. To this solution 1-hydroxybenzotriazole hydrate (46.74 g) was added and followed by ethyl-3(3-dimethylamino)propylcarbodiimide hydrochloride salt (68.74 g). The resulting solution was stirred at room temperature

10 TLC: Silica gel, 3:7 EtOAc-CH₂Cl₂, R_f=0.35, UV and PMA.

15 6.00 (s, 1H), 7.20 (m, 2H), 7.85 (m, 2H) ppm

20

CN1CCCCC1C(=O)N

30 solid (41 g).

To a stirred solution of the above solid (41 g) in CH_2Cl_2 (2 L) at room temperature under argon was added triethylamine (50 ml) and triphenylmethyl

chloride (83.41 g). After 1.5 hours, the resulting slurry was diluted with EtOAc, washed with water and brine, dried over anhydrous Mg_2SO_4 and evaporated in vacuo to give a gum. This was triturated with Et₂O-
5 pentane to give title compound (100.1 g) as a white solid in 96.5% yield.

TLC: Silica gel, 6:4 EtOAc-hexane, R_f =0.53, UV and PMA.

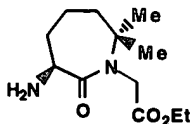
10

¹H-NMR (CDCl₃): δ=1.00 (s, 3H), 1.10 (s, 3H); 1.46 (m, 6H), 3.36 (m, 1H), 4.03 (m, 1H), 5.20 (d, 1H), 6.00 (s, 1H), 7.20 (m, 2H), 7.85 (m, 2H) ppm

15

¹³C-NMR (CDCl₃): 22.86, 25.81, 33.50, 34.23, 40.16, 51.97, 55.60, 71.89, 126.22, 127.61, 128.96, 146.48, 176.71 ppm

B(10).



20

To a stirred solution of Part B(9) compound (50 g, 125 mmole) in dry THF (1020 ml) at room temperature under argon was added simultaneously (at
25 same rate) a solution of lithium bis(trimethylsilyl)-amide (1.0 M solution in THF, 627.3 ml, 627.3 mmole) and a solution of ethyl bromoacetate (104.8 g, 627.3 mmole) in THF (523 ml) over the period of 1.0 hour. After the addition was complete, the solution was
30 stirred for 30 hours, quenched with saturated NH₄Cl solution (1.0 liter) and extracted with EtOAc (3x700 ml). The EtOAc extracts were combined, washed with

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saturated NaHCO_3 solution and brine, dried over anhydrous Mg_2SO_4 and evaporated in vacuo to afford a black oil. The experiment was repeated on the same scale to give a similar result. The combined black
5 oils was chromatographed on a column of silica gel (E. Merck, 230-400 mesh, 1.6 kg) eluting with EtOAc-hexane (1:4) to give a light yellow oil. This was dissolved in dry CH_2Cl_2 (2 L) and treated with trifluoroacetic acid (78 ml). The solution was
10 stirred at room temperature under argon for 1.0 hour and then evaporated in vacuo at 30° . The residue was diluted with 1.0 N HCl solution (400 ml) and washed with Et_2O (2x400 ml). The aqueous was carefully neutralized to pH=7-8 with solid NaHCO_3 (foaming) and
15 extracted with CH_2Cl_2 (3x1.2 L). The CH_2Cl_2 extracts were combined, dried over anhydrous Na_2SO_4 and evaporated in vacuo to afford a tlc homogeneous title compound (51.5 g) as a light brown oil in 84.7% yield.

20
TLC: Silica gel, 8:1:1 CH_2Cl_2 - CH_3OH -AcOH, $R_f=0.3$, PMA and Ninhydrin.

^1H -NMR (CDCl_3): δ =1.28 (t, 3H), 1.36 (s, 3H), 1.38
25 (s, 3H) 1.60 (m, 1H), 1.90 (m, 5H), 3.75 (m, 1H), 4.00 (d, 1H), 4.22 (q, 2H), 4.28 (d, 2H) ppm

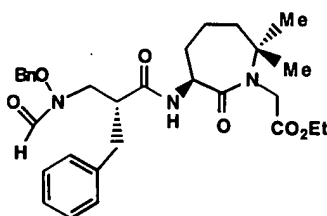
^{13}C -NMR (CDCl_3): 14.00, 20.06, 28.19, 30.07, 32.29,
39.98, 46.87, 53.20, 58.38, 60.73, 170.35, 177.06 ppm

30

Chemical structure of compound 10: A 1,4-dihydropyridine derivative. The 4-position is substituted with a 2-benzyloxycarbonyl-3-phenylpropanamide group. The 2-position is substituted with two methyl groups and an ethyl ester group.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99

D.



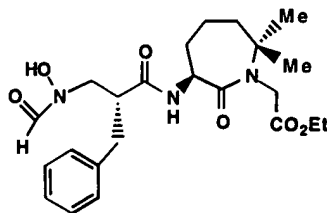
Acetic anhydride (500 μ L) was added to formic
 5 acid (5.0 mL) at 0°C and the mixture was stirred for
 30 minutes. Approximately 2.6 mL of this solution
 was added to a solution of Part C compound (208 mg,
 0.413 mmol) in THF (1.1 mL) at 0°C. After 30
 minutes, most of the solvent was removed by rotary
 10 evaporation and the residue was partitioned between
 EtOAc and saturated NaHCO_3 . The EtOAc extract was
 washed with brine, dried (Na_2SO_4), filtered and
 stripped to give title compound (216 mg, 97%) as an
 oily foam which was used directly in the next
 15 reaction without further purification.

TLC R_f 0.37 (EtOAc)

HPLC YMC S3 ODS column (6.0 x 150 mm); eluted with
 B:A solvent mixture, 40 to 100% B over a 20 minute
 20 linear gradient (solvent A: 90% H_2O -10% MeOH-0.2%
 H_3PO_4 ; solvent B: 0% H_2O -90% MeOH-0.2% H_3PO_4); flow
 rate 1.5 mL/min detecting at 220 nm; t_R = 17.2 min
 (100%).

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E.

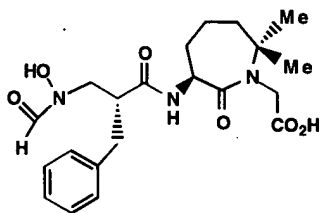


A solution of Part D compound (216 mg, 0.402 mmol) in absolute EtOH (5 mL) was hydrogenated (balloon) over 10% Pd/C (33 mg) at room temperature for 2 hours. The mixture was filtered through Celite, stripped, and azeotroped twice with EtOAc/Et₂O/hexanes to give title compound (174 mg, 97%) as an off-white foam.

TLC R_f 0.33 (5/95-HOAc/EtOAc)

HPLC YMC S3 ODS column (6.0 x 150 mm); eluted with B:A solvent mixture, 40 to 100% B over a 20 minute linear gradient (solvent A: 90% H₂O-10% MeOH-0.2% H₃PO₄; solvent B: 0% H₂O-90% MeOH-0.2% H₃PO₄); flow rate 1.5 mL/min detecting at 220 nm; t_R = 12.8 min (100%).

F.



A stirred solution of Part E compound (168 mg, 0.376 mmol) in MeOH (3 mL) at room temperature was treated with aqueous 1 N NaOH (3 mL). An additional

portion of aqueous 1 N NaOH (3 mL) was added after 3.5 hours. After a total of 6 hours, the mixture was made acidic with 5% KHSO₄ and extracted twice with EtOAc. The EtOAc extract was washed with brine, dried (Na₂SO₄), filtered and stripped. The residue was dissolved in a small amount of MeOH and EtOAc and triturated with Et₂O/hexanes to give title compound (134 mg, 86%) as an off-white solid/foam ([α]_D = +18.0° (c 0.5, CH₂Cl₂)).

10

TLC Rf 0.10 (5/95-HOAc/EtOAc)

HPLC YMC S3 ODS column (6.0 x 150 mm); eluted with B:A solvent mixture, 40 to 100% B over a 20 minute linear gradient (solvent A: 90% H₂O-10% MeOH-0.2%

15 H₃PO₄; solvent B: 0% H₂O-90% MeOH-0.2% H₃PO₄); flow rate 1.5 mL/min detecting at 220 nm; t_R = 9.00 min (>97.4%).

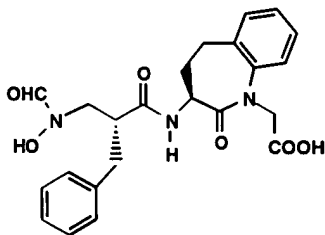
Anal. Calc'd for C₂₁H₂₉N₃O₆•0.75H₂O•0.3Et₂O

20 C, 58.57; H, 7.42; N, 9.23

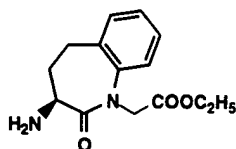
Found C, 58.31; H, 7.20; N, 8.99.

Example 4

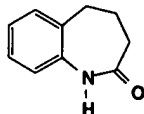
25 [S-(R*,R*)]-3-[[3-(Formylhydroxyamino)-1-oxo-2-(phenylmethyl)propyl]amino]-2,3,4,5-tetrahydro-2-oxo-1H-benzazepine-1-acetic acid



A.



A(1).



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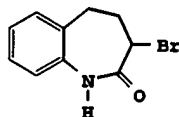
Solid sodium azide (26.0 g., 0.2 mole) was introduced into a 3-neck round-bottom flask with an overhead stirrer, made into a paste with warm water (26 ml), layered with chloroform (160 ml) and cooled down to 0° (ice-salt bath). The mixture was treated dropwise with concentrated sulfuric acid (11.2 ml, 0.5 eq.) over a period of 10 minutes, stirred for an additional 10 minutes then decanted into a flask containing anhydrous sodium sulfate. The dried solution was filtered through a glass wool plug in a funnel into a 500-ml round-bottom flask. Titration of an aliquot (1.0 ml) with 1.0 N NaOH using phenolphthalein as an indicator gave a normality of 1.7 N for the hydrazoic acid.

Tetralone (15.94 g, 0.108 mole) was added to the hydrazoic acid solution (0.136 mole or 1.25 eq.), heated to 40-45° (oil bath) then treated dropwise with 36.0 N H₂SO₄ (28.7 ml, 5 eq.) over a period of 1.0 hour. (Intense bubbling took place with each drop added for the first 30 minutes). The reaction mixture was cooled down to room temperature, poured into H₂O (720 ml) and stirred for 5 minutes. The solution was then extracted with EtOAc (3 x 250 ml) and the combined organic extracts were washed with

brine (100 ml), dried (anhydrous MgSO_4), filtered, evaporated to dryness and dried in vacuo. The crude product (17.819 g) was recrystallized from CH_2Cl_2 (70 ml) and Hexane (400 ml) to give title compound as off-white precipitates (10.017 g, m. pt. 138-140°C) with consistent ^1H -NMR and ^{13}C -NMR spectral data.

The mother liquor was chromatographed on a silica gel column (Merck, 240 g), eluting the column with EtOAc:Hexane (1:4) to give an additional amount of 5.058 g (total yield= 15.075 g, 85.6 %). TLC: R_f 0.37 (Silica gel; EtOAc:Hexane-1:1; UV).

A(2).

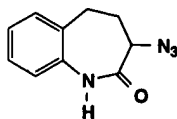


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A solution of Part A(1) compound (1.0 g, 6.20 mmoles) in dry CHCl_3 (15 ml) was cooled down to 0°C (ice-salt bath), treated with PCl_5 (1.5 g, 7.20 mmoles) followed by I_2 (15 mg) then stirred at 0°C under argon for 30 minutes. The yellow solution was treated with Br_2 (0.39 ml or 1.2 g, 7.51 mmoles), warmed up to room temperature and refluxed under argon for 4.0 hours. The mixture was then poured into ice-water (20 g), stirred and the phases were separated, washing the aqueous phase with CHCl_3 (25 ml). The combined organic extracts were washed with H_2O (5.0 ml), dried (anhydrous MgSO_4), filtered, evaporated to dryness and dried in vacuo. The crude product mixture was chromatographed on a silica gel column (Merck, 70 g), eluting the column with EtOAc:Hexane (1:9) to give title compound as off-white precipitates (1.137 g., m.pt. 170-172°, 70.1 %).

with consistent ^1H -NMR and ^{13}C -NMR spectral data.
TLC: R_f 0.13 (Silica gel; EtOAc:Hexane -1:4; UV).

A(3).

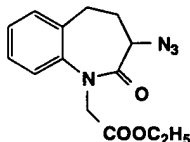


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A solution of Part A(2) compound (936 mg, 3.9 mmoles) and NaN_3 (300 mg, 4.6 mmoles) in dry dimethylsulfoxide (20 ml) was stirred at 60° (oil bath) under argon for 6.0 hours. The reaction mixture was cooled down to room temperature, poured into cold water (125 ml), stirred for 15 minutes and filtered, washing the solids formed with water. The crude product was dried *in vacuo* at 60° over drierite for 24 hours to give title compound (725 mg, m.pt. $150\text{--}152^\circ$, 91.9 %) as an off-white solid with consistent ^1H -NMR and ^{13}C -NMR spectral data. TLC: R_f 0.58 (Silica gel; EtOAc:Hexane- 1:4 then 1:1; UV).

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A(4).



A solution of Part A(3) compound (10.858 g, 53.7 mmoles) in dry tetrahydrofuran (100 ml) was treated with Bu_4NBr (1.791 g, 5.56 mmoles) and powdered KOH (3.937 g, 70.2 mmoles) followed by ethyl bromoacetate (6.8 ml, 61.3 mmoles). The reaction mixture was stirred at room temperature under argon for 1.5 hours then partitioned between H_2O (196 ml)

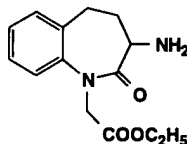
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and CH₂Cl₂ (2 x 375 ml). The combined organic extracts were washed with H₂O (2 x 196 ml) and brine (100 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness and dried *in vacuo*. The crude product was combined with the crude product mixture from a previous run (2.936 g, 12.86 mmole scale) and chromatographed on a silica gel column (Merck), eluting the column with Toluene:EtOAc (98:2) and EtOAc:Hexane (1:9) to give title compound as a solid (15.48 g, 93.5%)¹ with consistent ¹H-NMR and ¹³C-NMR spectral data.

TLC: R_f 0.63 (Silica gel; EtOAc:Hexane- 1:2; UV).

A(5).



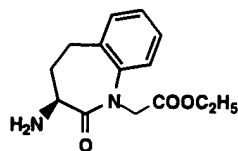
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A solution of Part A(4) compound (8.95 g, 31.0 mmoles) in absolute ethanol (50 ml) was treated with 10% Pd/C (443 mg) and hydrogenated at 45 psi for 3.5 hours, venting the Parr bottle every 30 minutes for the first 1.5 hours. The mixture was filtered through a Celite® pad in a millipore unit, washing the pad well with absolute ethanol (3 x 50 ml). The clear filtrate was evaporated to dryness and dried *in vacuo* to give title compound as a thick yellow syrup (7.929 g, 97.5%) with consistent ¹H-NMR and ¹³C-NMR spectral data. TLC: R_f 0.45 (Silica gel; CH₂Cl₂:CH₃OH- 9:1; UV).

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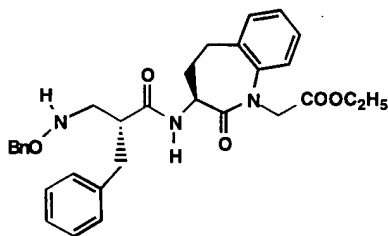
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A(6).



- A solution of Part A(5) compound (14.8 g, 56.4 mmoles) and L-tartaric acid (8.50 g) in hot absolute ethanol (118 ml) was kept overnight at 0°, at room temperature for 3 days and then at 0° for another 2 days. The solid that formed was recrystallized from absolute ethanol (118 ml) two more times until a consistent specific rotation was obtained. The precipitates (6.319 g) from the second recrystallization was then suspended in EtOAc (100 ml), treated with 10% NH₄OH (12 ml) and stirred for 5 minutes. The organic phase was separated, washed with 10% NH₄OH (10 ml) and brine (15 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness and dried in vacuo to give title compound as a white solid (3.927 g, m.pt. 105-107°, 26.5%) with consistent ¹H-NMR and ¹³C-NMR spectral data. [α]_D = -277° (c 0.99, EtOH). TLC : R_f 0.45 (Silica gel; CH₂Cl₂:CH₃OH- 9:1; UV).

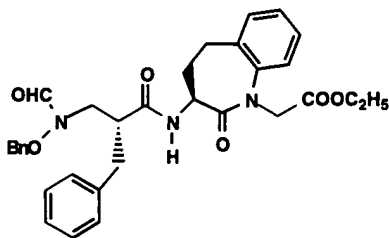
B.



Example 3 Part A ephedrine salt (414 mg, 0.93 mmole), was partitioned between 5 % KH_2PO_4 (adjusted to pH 2.5; 4.0 ml) and EtOAc (2 x 20 ml) and the combined organic extracts were washed with brine (4.0 ml), dried (anhydrous Na_2SO_4), filtered, evaporated to dryness and dried in vacuo to give the free acid of the Example 4 Part A compound as a clear syrup (286.6 mg, 100 % crude yield).

A solution of the above free acid (286.6 mg, 0.93 mmole) in dry CH_2Cl_2 (6.0 ml) was cooled to 0°C (ice-salt bath) and treated sequentially with a solution of the above free amine (271 mg) in dry CH_2Cl_2 , HOBT· H_2O (126.1 mg, 0.93 mmole) and EDAC (185.4 mg, 0.97 mmole). The reaction mixture was stirred at 0°C for 1.0 hour, at room temperature for 2.0 hours, then partitioned between EtOAc (2 x 20 ml) and H_2O (4.0 ml). The organic extracts were washed with 5% KH_2PO_4 (adjusted to pH 2.5; 4.0 ml), H_2O (4.0 ml), saturated NaHCO_3 (4.0 ml) and brine (4.0 ml), dried (anhydrous Na_2SO_4), filtered, evaporated to dryness and dried in vacuo. The crude product was chromatographed on a silica gel column (Merck, 70 g.), eluting the column with EtOAc:Hexane mixtures (1:3; 1:1) to give pure title compound (202 mg) and impure product. A second chromatography gave title compound as a syrup (total of 292.1 mg, 59.3%) with consistent ^1H -NMR and ^{13}C -NMR spectral data. TLC: R_f 0.32 (Silica gel; EtOAc:Hexane -1:1; UV).

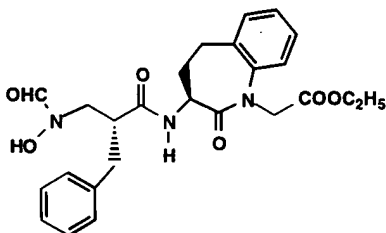
C.



- 5 A cooled solution of HCOOH (5.0 ml) was treated with acetic anhydride (Ac₂O) (0.5 ml) and stirred at 0°C for 30 minutes. A solution of Part B compound (288 mg, 0.54 mmole) in dry THF (1.5 ml) was cooled to 0°C (ice-salt bath), treated with the above Ac₂O/HCOOH mixture (3.4 ml) and stirred at 0°C for
- 10 1.0 hour. The reaction mixture was evaporated to dryness and the residual syrup was dissolved in EtOAc (40 ml), washed with saturated NaHCO₃ (5.0 ml) and brine (5.0 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness, evaporated from toluene and
- 15 dried *in vacuo* to give title compound as a syrup (311.3 mg, 100 % crude) with consistent ¹H-NMR and ¹³C-NMR spectral data. TLC: R_f 0.18 (Silica gel; EtOAc:Hexane (1:1; UV).

20

D.



A solution of Part C compound (311 mg) in CH₃OH (10 ml) was treated with 10% Pd/C (53 mg) and

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hydrogenated (balloon) at room temperature for 2.0 hours. The reaction mixture was diluted with CH₃OH (10 ml) and filtered through a Celite® pad in a millipore unit, washing the pad well with CH₃OH (3 x 10 ml). The clear filtrate was evaporated to dryness and dried *in vacuo* to give title compound as a syrup (256.7 mg, 100% crude) with consistent ¹H-NMR and ¹³C-NMR data. TLC: R_f 0.25 (Silica gel; CH₂Cl₂:MeOH- 9:1; UV).

10

E. [S-(R*,R*)]-3-[[3-(Formylhydroxyamino)-1-oxo-2-(phenylmethyl)propyl]amino]-2,3,4,5-tetrahydro-2-oxo-1H-benzazepine-1-acetic acid

A solution of Part D compound (256.7 mg) in CH₃OH (3.5 ml) was treated with 1.0 N NaOH (2.17 ml, 4 eq) and stirred at room temperature for 1.0 hour under argon. The reaction mixture was brought to pH 1.0 with 5% KHSO₄ (9.45 ml), extracted with EtOAc (40 ml) and the organic extract washed with brine (5.0 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness and dried *in vacuo*. The crude product was triturated with CH₂Cl₂:Hexane (1:4-25 ml) and hexane (20 ml) then dried *in vacuo* to give title compound as an amorphous off-white solid (215.6 mg, 90.4%) with consistent MS, IR, ¹H-NMR and analytical data. TLC: R_f 0.30 (Silica gel; EtOAc:HOAc- 95:5; UV).

[α]_D = -332.8° (c 0.558, CH₃OH)

HPLC: t_R = 5.21 min (95.8% R isomer); t_R = 9.58 min (3.59% S isomer); YMC S3 ODS-A 150 x 6 mm; 220 nm, flow rate = 1.5 ml/min; 56% (10% H₂O- 90% CH₃OH- 0.2% H₃PO₄)/44% (90% H₂O- 10% CH₃OH-0.2% H₃PO₄), isocratic.

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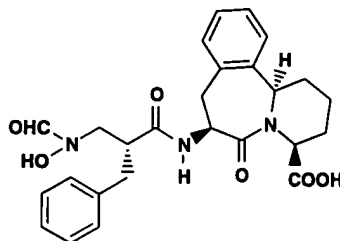
Anal. Calc'd for $C_{23}H_{25}N_3O_6$:

C, 62.86; H, 5.73; N, 9.56

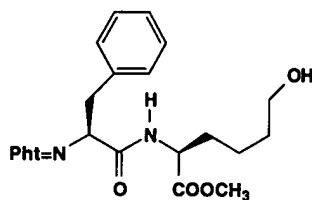
Found: C, 62.88; H, 5.98; N, 9.20.

5

Example 5



A.



10

A solution of L-hydroxynorleucine (2.0 g, 13.6 mmoles) in dry methanol (70 ml) was saturated with HCl gas until a clear yellow solution was obtained. The reaction mixture was cooled to room temperature, stirred for 2.0 hours, evaporated to dryness, evaporating the syrup once from toluene (100 ml) then evaporated in vacuo to give the ester as a yellow oil. The crude ester was dissolved in dry CH_2Cl_2 (50 ml) and dry DMF (15 ml), treated with NMM (2.5 ml, 22.7 mmoles) and cooled to $0^\circ C$ (ice-salt bath). The mixture was treated with N-phthaloyl-L-phenyl-alanine (4.0 g, 13.6 mmoles), HOBT $\cdot H_2O$ (1.89 g, 13.99 mmoles) and EDAC (2.87 g, 14.98 mmoles), stirred at $0^\circ C$ for 25 minutes and at room temperature for 2.0 hours.

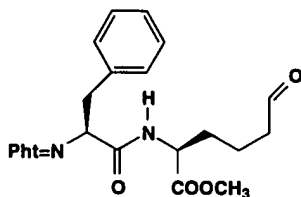
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The reaction mixture was partitioned between EtOAc (2 x 200 ml) and H₂O (60 ml) and the combined organic extracts were washed sequentially with 0.5 N HCl (60 ml), H₂O (60 ml), 1/2 saturated NaHCO₃ (60 ml) and brine (60 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness and dried *in vacuo*. The crude product mixture was chromatographed on a silica gel column (Merck, 200 g), eluting the column with EtOAc to give the desired product as a syrup (4.0 g). An additional 321 mg was obtained on re-chromatography of the impure fractions to give title compound (4.32 g, 73%) with consistent ¹H-NMR and ¹³C-NMR spectral data. TLC: R_f 0.43 (Silica gel; EtOAc; UV).

B.



A solution of oxalyl chloride (1.02 ml, 11.7 mmol) in dry CH₂Cl₂ (56 ml), was cooled to -78°C (dry-ice-acetone bath), treated with a solution of dry DMSO (1.67 ml, 21.6 mmol) in CH₂Cl₂ (2.0 ml) and stirred at -78°C for 20 minutes. The mixture was treated with a solution of Part A compound (4.29 g, 9.78 mmol) in dry CH₂Cl₂ (22 ml), stirred at -78°C for another 15 minutes, then treated with triethylamine (8.4 ml). The reaction mixture was stirred at -78°C for 5.0 minutes, allowed to come to room temperature over a period of 45 minutes, then partitioned between EtOAc (200 ml) and 0.5 N HCl (2 x

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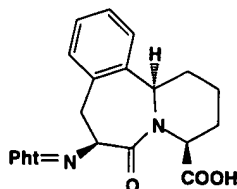
COC(=O)[C@H]1CCCCN1C(=O)[C@H](Cc2ccccc2)Nc3ccccc3

15

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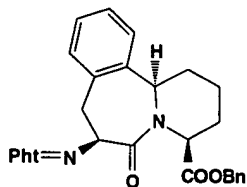
25

D.



- A solution of Part C compound (2.923 g, 6.99
 5 mmoles) in dry CH_2Cl_2 (14 ml) was treated with
 triflic acid (4.15 ml, 6.7 eq) and the resulting
 yellow solution was stirred at room temperature for
 20 hours. The reaction mixture was then poured into
 ice-water (100 ml), extracted with EtOAc (3 x 100 ml)
 10 and the combined organic extracts washed with H_2O (2
 x 25 ml) and brine (25 ml), dried (anhydrous Na_2SO_4),
 filtered, evaporated to dryness and dried *in vacuo*.
 The crude product mixture was chromatographed on a
 silica gel column (Merck), eluting the column with
 15 EtOAc:Hexane mixtures (1:1; 2:1) and EtOAc:HOAc
 (100:1). The desired fractions were combined,
 evaporated to dryness and dried *in vacuo* to give
 impure title compound as a solid foam (1.238 g, 42%)
 with consistent ^1H -NMR and ^{13}C -NMR spectral data.
 20 TLC : R_f 0.73 (Silica gel; EtOAc:HOAc-95:5; UV).

E.



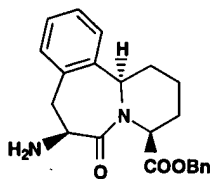
- 25 A solution of Part D compound (1.238 g, 3.06
 mmols) in dry DMF (3.5 ml) was treated sequentially
 with benzyl bromide (0.35 ml, 2.94 mmols) and Cs_2CO_3

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(450 mg, 1.38 mmoles) then stirred at room temperature for 3.0 hours. The mixture was diluted with EtOAc (50 ml), washed with H₂O (5.0 ml), 0.5 N HCl (5.0 ml) and brine (5.0 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness and dried in vacuo. The crude product (1.63 g) was chromatographed on a silica gel column (Merck), eluting the column with EtOAc:Hexane (1:3) to give title compound as a syrup (586.4 mg, 39%) with consistent ¹H-NMR and ¹³C-NMR spectral data.

TLC: R_f 0.45 (Silica gel; EtOAc:Hexane-1:1; UV).

F.



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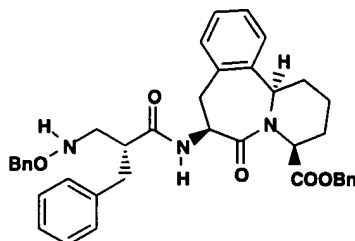
A solution of Part E compound (586 mg, 1.18 mmoles) in dry methanol (15 ml) was treated with NH₂NH₂·H₂O (66 μl, 1.2 eq) and stirred at room temperature for 48 hours. The reaction mixture was diluted with Et₂O (50 ml) and filtered through a millipore unit, washing the solids well with Et₂O (40 ml). The clear solution was evaporated to dryness and the solids obtained were suspended in CH₂Cl₂ (90 ml) and the solution filtered through a millipore unit, washing the solids well with CH₂Cl₂ (40 ml). The combined organic extracts were washed with brine (15 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness and dried in vacuo to give title compound as a thick syrup (351 mg, 82 %) with a consistent ¹H-NMR spectrum.

TLC: R_f 0.42 (CH₂Cl₂:MeOH-9:1; UV, Ninhydrin)

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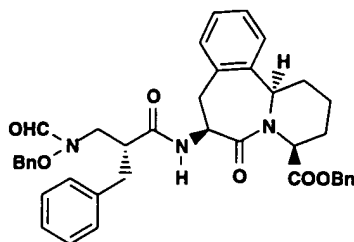
G.



- 5 Example 3 Part A ephedrine salt (538 mg, 1.2
mmoles), was partitioned between 5% KH₂PO₄ (adjusted
to pH 2.5; 5.4 ml) and EtOAc (2 x 22 ml) and the
combined organic extracts were washed with brine (5.4
ml), dried (anhydrous Na₂SO₄), filtered, evaporated
10 to dryness and dried in vacuo to give the free acid
of the ephedrine salt as a clear syrup (323 mg, 100%
crude yield).
- A solution of the free acid in dry CH₂Cl₂
(8.0 ml) was cooled to 0°C (ice-salt bath) and
15 treated sequentially with a solution of Part F
compound (351 mg, 0.96 mmole) in dry CH₂Cl₂ (2.0 ml),
HOBT·H₂O (163 mg, 1.2 mmoles) and EDAC (240 mg, 1.25
mmoles). The reaction mixture was stirred at 0°C for
1.0 hour, at room temperature for 1.5 hours, then
20 partitioned between EtOAc (40 ml) and H₂O (5.0 ml).
The organic extracts were washed with 5 % KH₂PO₄
(adjusted to pH 2.5; 5.0 ml), H₂O (5.0 ml), saturated
NaHCO₃ (5.0 ml) and brine (5.0 ml), dried (anhydrous
Na₂SO₄), filtered, evaporated to dryness and dried
25 in vacuo. The crude product (810 mg) was chromato-
graphed on a silica gel column (Merck), eluting the
column with EtOAc:Hexane (1:3) to give pure title
compound (494 mg, 65%) as a solid foam with
consistent ¹H-NMR and ¹³C-NMR spectral data.

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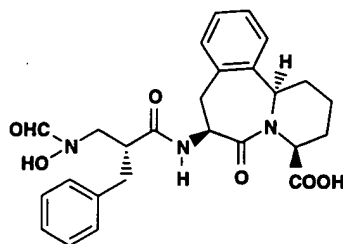
H.



A cooled solution (0°C, ice-salt bath) of HCOOH (5.0 ml) was treated with Ac₂O (0.5 ml) and stirred at 0°C for 30 minutes. A solution of Part G compound (493 mg, 0.78 mmole) in dry THF (2.2 ml) was cooled to 0°C (ice-salt bath), treated with the above Ac₂O/HCOOH mixture (4.9 ml) and stirred at 0°C for 1.5 hours. The reaction mixture was evaporated to dryness, evaporated from Et₂O (50 ml) and the residual syrup was dissolved in EtOAc (60 ml), washed with saturated NaHCO₃ (7.0 ml) and brine (7.0 ml), dried (anhydrous Na₂SO₄), filtered, evaporated to dryness, evaporated from toluene and dried in vacuo to give title compound as a syrup (558.3 mg, 100 % crude) with consistent ¹H-NMR and ¹³C-NMR spectral data.

TLC: R_f 0.2 (Silica gel; EtOAc:Hexane-1:1; UV).

I.



5 A solution of Part H compound (535 mg, 0.78 mmole) in CH₃OH (15 ml) was treated with 10 % Pd/C (83 mg) and hydrogenated (balloon) at room temperature for 4.0 hours. The reaction mixture was diluted with CH₃OH (15 ml) and filtered through a celite pad in a millipore unit, washing the pad well
10 with CH₃OH (3 x 15 ml). The clear filtrate was evaporated to dryness and dried *in vacuo* to give a syrup (354.8 mg) which was triturated with CH₂Cl₂:Hexane (1:5-30 ml) and hexane (25 ml) then dried *in vacuo*. Title compound was obtained as an
15 off-white solid foam (348.5 mg, 90%).

TLC: R_f 0.38 (Silica gel; CH₂Cl₂:MeOH- 9:1; UV).

MS (M+H)⁺ = 480

[α]_D = +44.6° (c 0.52, CH₃OH)

20

HPLC : t_R = 11.72 min (95.9%); YMC S3 ODS-A 150 x 6 mm; 220 nm, flow rate = 1.5 ml/min; 55% (10% H₂O- 90% CH₃OH- 0.2% H₃PO₄)/ 45% (90% H₂O- 10% CH₃OH-0.2% H₃PO₄), isocratic.

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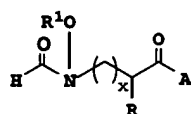
Anal. Calc'd for C₂₆H₂₉N₃O₆•0.4 H₂O•0.14 Hexane (Eff. Mol. Wt. = 497.08):

C, 64.63; H, 6.83; N, 8.46

Found: C, 64.24; H, 6.43; N, 8.12

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The following are examples of additional compounds of the invention which may be prepared employing procedures set out hereinbefore and in the working Examples.



Example No.	R ¹	x	R	A
6	H	1	CH ₂ Ph	
7	H	1	CH ₂ Ph	
8	H	1	CH ₂ CH(CH ₃) ₂	
9	H	1	CH ₂ Ph	
10	H	1	CH ₂ CH(CH ₃) ₂	
11	H	1	CH ₂ Ph	

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